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FOREIGN TECHNOLOGY DIVISION

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by

Chien Cheng-teh

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THE PROGRESS OF DIGITAL COMPUTERS ON BOARD AN AIRPLANE

CHIEN Cheng-teh

Electronic digital computers have been widely used on modern airplanes. This article is a simple introduction to a comparison of computers both on board and on the ground, their special features, and the recent developments.

Modern military aircraft have to perform missions such as reconnaissance, breaking a siege, intercepting, fighting, anti-submarine warfare, ECM, and transportation. Thus, they are equipped with much electronic equipment and need a computer to compute, analyze, process, control, and display messages from this equipment. They also need an electronic computer to supervise those functions and to send out the correction signals immediately upon the malfunction of any equipment. With the automatic sequence in aircraft weapon systems, electronic computers accomplish almost instantly a task which required several seconds or several minutes by a pilot or a mechanical system in the past.

The on-board computer is limited and affected by factors of the aircraft environment. Therefore, it is required to have small volume, light weight, low power consumption, high reliability, and to operate normally under poor environmental conditions.

Recently, on-board computers developed very rapidly. There are three main reasons: 1 - the increasing need for aviation electronic facilities due to the appearance and development of high performance aircraft; it is necessary to use electronic computers to do the high speed computations; 2 - the tremendous progress of the medium and large integrated circuits which are used as electronic components has provided favorable conditions for on-board aircraft computers to use these advanced circuits; 3 - the mature experiences accumulated from the use of tubes, transistors and integrated circuits in the ground computers have provided benefits in developing on-board aircraft computers.

At present, the on-board aircraft computer has reached the technical level of ground computers in many aspects. These are briefly discussed below.

STORAGE

The on-board aircraft computer is the same as a ground computer. It consists of storage, computation, control, and input and output facilities. The storage capacity is an important aspect of the computation ability. Most on-board aircraft computers use magnetic core storage (Fig. 1) (for details see October issue of this magazine for 1974). The storage capacity is 131,000 to 262,000 words and the read-write cycle is about 1 microsecond. But, considering the problems of nuclear radiation and electromagnetic radiation in modern war, the antinuclear radiation ability of magnetic core storage is rather poor. When data are recorded in magnetic core storage during a nuclear explosion, mistakes often occur. Thus, some on-board aircraft computers use magnetic-wire storage. It has better antinuclear radiation and anti-electromagnetic radiation characteristics. The power consumption is lower than that of magnetic core storage. The speed is fast, and it can be mass produced.

The magnetic-wire storage is shown in Fig. 2. The wires are beryllium copper wires. Each wire is plated with permalloy film sections, the magnetic film being is used as storage elements. To magnetize the magnetic film, it is easier to magnetize in the direction around the copper wire. When a direct current passes through the copper wire, the magnetic film gets magnetized. When the current passes through the copper wire in different directions, the magnetized directions in relation to the copper wire are also different, either clockwise or counterclockwise, representing the "1" or "0" of the binary system respectively. These parallel copper wires are called word lines, and the flat conducting plates which are perpendicular to the copper wires are called position lines. By applying a current to the corresponding position line, the stored message can be read. By applying current on both the position line and the word line at the same time, a new message is recorded.

In the early 1960's, the making of integrated circuits succeeded. In the late 1960's, medium and large integrated circuits were used in the on-board airplane computers to replace transistorized discrete components. The use of semiconductor storage (Fig. 3) in the on-board aircraft computer began in the early 1970's and replaced the magnetic core storage. For example, by using semiconductors, the storage of an on-board aircraft computer could be expanded to a capacity of 65,000 words, and the read-write cycle is 750 nanosecond. Besides, the volume is small, and the power consumption is low.

We will use a 1024 MOS memory as a example. On a large scale integrated circuit made of a metal-oxide semiconductor with a size of 5 x 5 mm^2 (equivalent to an area of 1/4 of a fingernail), about 5,000 MOS transistors of different sizes are arranged to store 1024 binary numbers. By using it to replace the magnetic core storage, volume is greatly reduced. For instance, originally a cabin was required to store the data stored in magnetic core storage; now, a volume of the size of several books is enough to store the

semi-conductor storage. The read-write speed increased 5 to 7 times with the advantages of low power consumption, easy adjustment, stability, reliability, etc.

The disadvantage of the semiconductor storage is that the stored data are completely lost when the electricity is off. Therefore, the calculator has its own battery which turns on automatically when the power source has trouble.

Recently, a new type storage - magnetic bubble storage (Fig. 4) has been successfully developed. It has such advantages as permanent storage, high density, high reliability, low cost, etc. It shall be used in the computer on-board aircraft or space flight vehicles.

At present, the magnetic bubble material developed by every country is mainly of two kinds. One is ferric oxide monocrystalline thin plate or garnet monocrystal. Another kind is some non-crystalline magnetic bubble film made of an alloy of ferrite, cobalt and rare earth metals such as gadolinium. These magnetic thin films which are acted upon by a magnetic field and show S polarity can produce an N polarity with regular cylindrical shapes with diameters of several microns. This magnetic area of the cylindrical portion is called a magnetic bubble. One could assume that a state that has a magnetic bubble represents "1", and the state without a magnetic bubble represents "0". Magnetic bubbles with these two states are used to store binary digital messages. By feeding external impulses, messages could immediately be recorded in or read out, so the computer actually has a faster processing speed. Besides, magnetic bubble storage costs less, the structure is simple, and storage density could be as high as several ten thousand to several million units per square centimeter. But, other types of high density storage generally have only five thousand to ten thousand units.

USE OF NEW TECHNOLOGY

In order to increase computing speed and computing capability, parallel operation is commonly used, and the speed of message exchange increases even greater when dual path digital lines, command, and data cross input and output are used. A multiplexing main line is used between the computer and other on-board airplane electronic facilities, so that the speed of message transmission could be increased. No extra wiring is needed whenever the on-board airplane electronic facility is changed, which is another advantage.

In order to increase the speed of multiplication and division of the on-board airplane computer, high speed multiplication and division is employed; in order to reduce the number of searches through the storage unit, a general-purpose accumulator is used to register the intermediate results which could be computed among the registers.

An on-board computer sometimes uses multi-processors, that is, one computer uses more than two processors, memories and input/output devices. Each processor is allowed to search any memory storage, so that both processors are able to search different memories at the same time.

By using the above mentioned new technology, the speed of the entire computer is made very high. Some computers makes several hundred thousand computations per second, some even have a computing capability of more than a million times per second.

In the early 1960's, an on-board airplane computer seldom used software, but in the late 1960's some on-board airplane computers not only used assembly language, but also used higher-order language to solve the problems for which the computer continuously becomes more complicated and its program design mission continuously increases.

In order to locate and isolate the trouble more effectively, the on-board computer also uses diagnostic procedures now. By setting up a special testing instruction and using dynamic diagnostic methods, manual operations of maintenance and diagnosis have basically been eliminated, and the diagnostic procedures have also been reduced. Having the diagnostic procedures, the efficiency of maintenance could be improved and components and devices could be changed on time.

At present, one on-board computer is used in many ways. Most computations need real-time processing; therefore, a multiple priority interrupting system is built in. Thus, under the control of a processing operation, within the allowed time, and considering the degree of importance of the mission, the important mission is processed first and then the less important mission.... If there is any time left, the computer could do self-testing.

The ground computer had been standardized, serialized, and modularized; the on-board aircraft computer is also marching in the same direction. The so-called standardization is to put standard connectors on the computer so that the input/output device could be conveniently connected to the processor. Serialization is to match computers of different sizes and functions to satisfy various uses. All central processors, storage, and input/output devices could be modularized to comprise some appropriate computer as required.

It is worth mentioning that many factories that produce on-board aircraft computers at present produce ground computers at the same time. Therefore, the matured advantages and experiences gained from ground computers could be applied to on-board computers, thus reducing research time and increasing reliability.

The general techniques used in the present high performance of on-board aircraft computers have been introduced briefly above. Certainly, they are not applicable to every computer that is

complicated and with a high level of combination. Sometimes it is necessary to have a simple single functional on-board computer, such as a fuel control computer or navigation computer, in order to guarantee the normal execution of basic functions of the aircraft for a safe return. Consequently, the modern aircraft installs several computers which are combined with other electronic facilities to make a reliable avionic system which guarantees the tactical performance of the aircraft to the utmost.

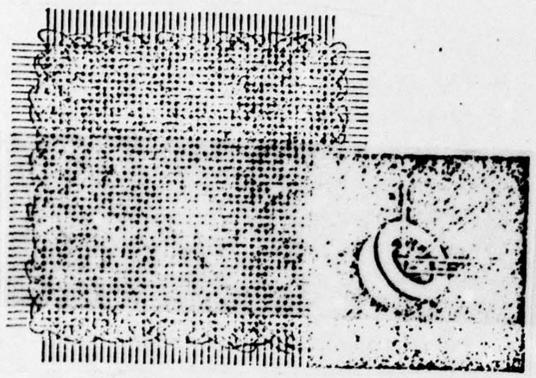

Fig. 1. Magnetic core storage.

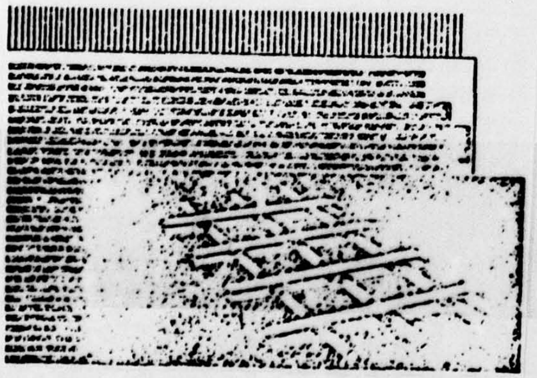

Fig. 2. Magnetic wire storage.

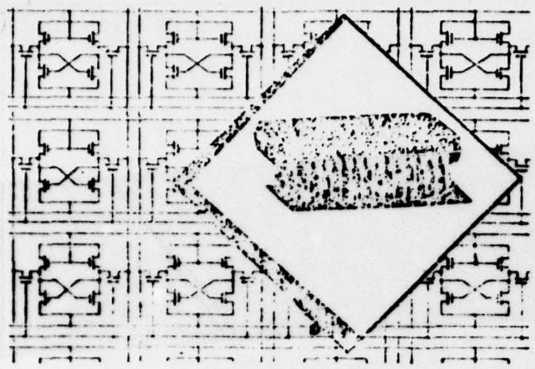

Fig. 3.

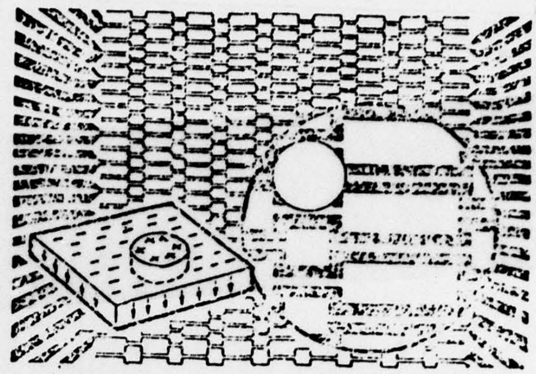

Fig. 4.

Fig. 3. Semiconductor storage.

Fig. 4. Magnetic bubble storage.

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